PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Serial No.	:	10/750,064	Confirmation No.:	9115
Applicants	:	Maltsev et al.		
Filed	:	December 30, 2003		
TC/A.U.	:	2611		
Examiner	:	Burd, Kevin Michael		
Title	:	Adaptive Channel Equalizer for Wireless System		
Docket No.	:	1020.P16742		
Customer No.	:	57035		

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

DECLARATION UNDER 37 C.F.R. §1.131

1. I, the undersigned, am an inventor for the Patent Application (hereinafter "the Application") identified above.

2. The subject matter of the Application was conceived prior to November 4, 2003, as evidenced by the "Intel Invention Disclosure 30545" dated February 28, 2003, which is attached hereto as Exhibit A.

3. I have reviewed the subject matter of currently pending claims 1-6, 10-16, and 18. The "Intel Invention Disclosure 30545" fully supports the subject matter of claims 1-6, 10-16, and 18 of the Application.

4. My employer approved the preparation and filing of the Application directed to the subject matter described in the "Intel Invention Disclosure 30545."

5. On December 15, 2003 I reviewed the final draft and authorized the filing of the Application.

6. The Application was filed in the United States Patent Office on December 30, 2003, constructively reducing the invention to practice.

7. I hereby declare that all declarations made herein of my own knowledge are true, and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Alexander A. Maltsev — 28th August 2008 Date

Ali S. Sadri — Date

Andrey V. Pudeyev — 28th of August, 2008 Date

Alexey E. Rubtsov — Date

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Alexander A. Maltsev	Date
Ali S. Sadri	September 3, 2008 Date
Andrey V. Pudeyev	Date
Alexey E. Rubtsov	Date

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Alexander A. Maltsev	Date
Ali S. Sadri	Date
Andrey V. Pudeyev	Date
Alexey E. Rubtsov	5 September 2008 Date

EXHIBIT A

INTEL INVENTION DISCLOSURE

ATTORNEY-CLIENT PRIVILEGED COMMUNICATION
located at http://legal.intel.com/patent/index.htm

30545

DATE: 02/28/03

WIRELESS/CTG/CITL/WTD

It is important to provide accurate and detailed information on this form. The information will be used to evaluate your invention for possible filing as a patent application. **Invention Disclosure forms MUST be sent electronically via email to your manager/supervisor who should then forward with their approval to our email account "invention disclosure submission."** If you have any questions, please call **8-264-0444.**

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Supervisor:	WWID:	M/S:	Phone #:

(PROVIDE SAME INFORMATION AS ABOVE FOR EACH ADDITIONAL INVENTOR)

2. Title of Invention:
Adaptive channel equalizer with decision directed feedback

3. What technology/product/process (code name) does your invention relate to (be specific if you can)
OFDM – orthogonal frequency division multiplexing, IEEE 802.11a

4. Include several key words to describe the technology area of the invention in addition to # 3 above:
OFDM systems, equalizer,channel tracking, amplitude and phase compensation

5. Stage of development (i.e. % complete, simulations done, test chips if any, etc.):
Simulations done

6a. Has a description of your invention been (or planned to be) published outside of Intel:
YES
If YES, was the manuscript submitted for pre-publication approval through the Author Incentive Program:
NO
If YES, please identify the publication and the date published:

6b. Has your invention been used/sold or planned to be used/sold by Intel or others?
NO
If YES, date it was sold or will be sold:

6c. Does this invention relate to technology that is or will be covered by a SIG (special interest group)/standard or specification?
NO
If YES, name of SIG/standard/specification:

6d. If the invention is embodied in a semiconductor device, actual or anticipated date of tapeout?

6e. If the invention is software, actual or anticipated date of any beta tests outside Intel:

7. Was the invention conceived or constructed in collaboration with anyone other than an Intel blue badge employee or in performance of a project involving entities other than Intel (e.g. government, other companies, universities or consortia)? NO: X If YES, name of individual or entity:

8. Is this invention related to any other invention disclosure that you have recently submitted? If so, please give the title and inventors:
"ADAPTIVE CHANNEL ESTIMATION FOR ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING SYSTEMS OR THE LIKE" by Alexander A. Maltsev, Andrey V. Pudeyev, Ali S. Sadri

PLEASE READ AND FOLLOW THE DIRECTIONS ON HOW TO WRITE A DESCRIPTION OF YOUR INVENTION

Try to limit your description to 2-3 pages
Do NOT attach a presentation, white paper, or specification
ANSWER ALL OF THE QUESTIONS BELOW

Please provide a description of the invention and include the following information:

1. **Describe in detail what the components of the invention are and how the invention works.**

This invention proposes a novel adaptive equalization scheme with decision directed feedback for OFDM system. The purpose of this scheme is to compensate time-variant fluctuation of the frequency-selective channel caused by Doppler effect. The proposed scheme, in addition to the conventional scheme that averages and updates estimated channel coefficient on each subcarrier [1], averages channel coefficients of adjacent subcarriers, exploiting a smoothing window. This additional smoothing in frequency domain improves accuracy of channel equalization.

Proposed scheme is a part of the OFDM receiver and used for channel tracking and signal equalization. It consists of three additional to usual OFDM system blocks. Fig.1 shows the proposed scheme, incorporated in digital part of usual OFDM receiver.

Block 1 is a channel estimator. It uses special training symbols to obtain channel transfer function estimate (in frequency domain). In one embodiment channel estimator can exploit least square (LS) algorithm with smoothing of the obtained channel estimates in frequency domain. Smoothing window length may be fixed or chosen adaptively on the basis of channel length estimate [3]. The output of block 1 – Least Square Channel Estimator is the initial state of the proposed channel-tracking scheme.

Block 2 – averaging circuit is a core of the proposed adaptive channel equalizer. It takes LS channel estimate as initial state and updates the channel equalizer coefficients by using information from block 3 – channel correction device. Averaging circuit provides averaging channel coefficients form block 3 on the several OFDM symbols in time domain. In addition, it makes smoothing in frequency domain (through the subcarriers) in the same way as at the LS with smoothing channel estimator.

Block 3 - channel correction device is used to obtain channel estimate from only one OFDM symbol, by division received non-equalized OFDM symbol on the corresponded correct symbol. In one embodiment, to obtain correct symbol we use feedback symbol from the Demapper block of OFDM system. In another embodiment, it is possible to take feedback signal from the decoder, but it makes system more complex.

Block 4 is usual mapper (BPSK, QPSK 16-QAM, 64-QAM, etc).

Block 5 is standard interleaver for OFDM systems.

Block 6 is decoder for convolutional coder, used in OFDM system. It may be hard decision or soft decision decoder.

Blocks 4-6 may not be a special part of the proposed device, but can be embedded in the transmitter part on the OFDM transceiver, and used in our scheme in the receiving stage, when all transmitter devices is inactive.

The scheme is work as follows:

The received signal is fed into FFT, which recovers the data subcarriers. Then, to eliminate the effect of multipath fading, OFDM symbol is divided by the equalizer coefficients. These coefficients are equal to the channel estimates for first N OFDM symbols. For the next N symbols equalizer coefficients are equal to averaged channel estimates from block 3. We use "N-size block averaging" instead of "moving average". It allows to store in memory only N_{FFT} (size of FFT) variables in comparison with $N^* N_{FFT}$ in the case of "moving average". At the next cycle, we use average over previous N channel estimates from block 3 to equalize next N symbols and so on. Value of N (block size) can be determined on the basis of a priori information about channel coherence time.

To evaluate performance of the proposed scheme, we have embedded it into the OFDM 802.11a transceiver pipeline model. For simulation we have used Jakes channel model with Doppler spread (see [2]). Parameters of this model are shown at Table 1.

Channel Model	Jakes, [2]
Delay spread	50 ns, Rayleigh
Doppler spread	50 Hz, Flat
Number of reflectors	9

Table 1. Jakes channel model parameters.

We use 16-QAM modulation with hard decision decoder (rate 3/4). Packet length was 4000 bytes (about 450 symbols)- about 2 ms duration.

It can be seen, that exploiting of the proposed scheme with smoothing in frequency domain gives about 0.5-0.7 dB equivalent SNR gain in comparison to scheme without frequency smoothing. Performance of OFDM system without channel tracking is decreased dramatically because of Doppler spread.

2. Describe advantage(s) of your invention over what is currently being done.

- Feedback from the demapper block reduces complexity without significant loss of performance.

- Feedback from the demapper block allows avoiding long delay, concerned with feedback from the decoder.
- Exploiting "block averaging" instead of "moving average" decreases computational burden and economizes memory.
- Equalizer coefficients smoothing in frequency domain improve equalizer performance. (Significant improvement over prior art)
- The scheme is adopted to work with new bit and power loading algorithms.
- Capability to use block codes with long block size with the proposed adaptive equalizer configuration (e.g LDPC, Turbo, Substantial differentiation from the prior art)

3. **You MUST include at least one figure illustrating the invention. If the invention relates to software, include a flowchart or pseudo-code representation of the algorithm.**

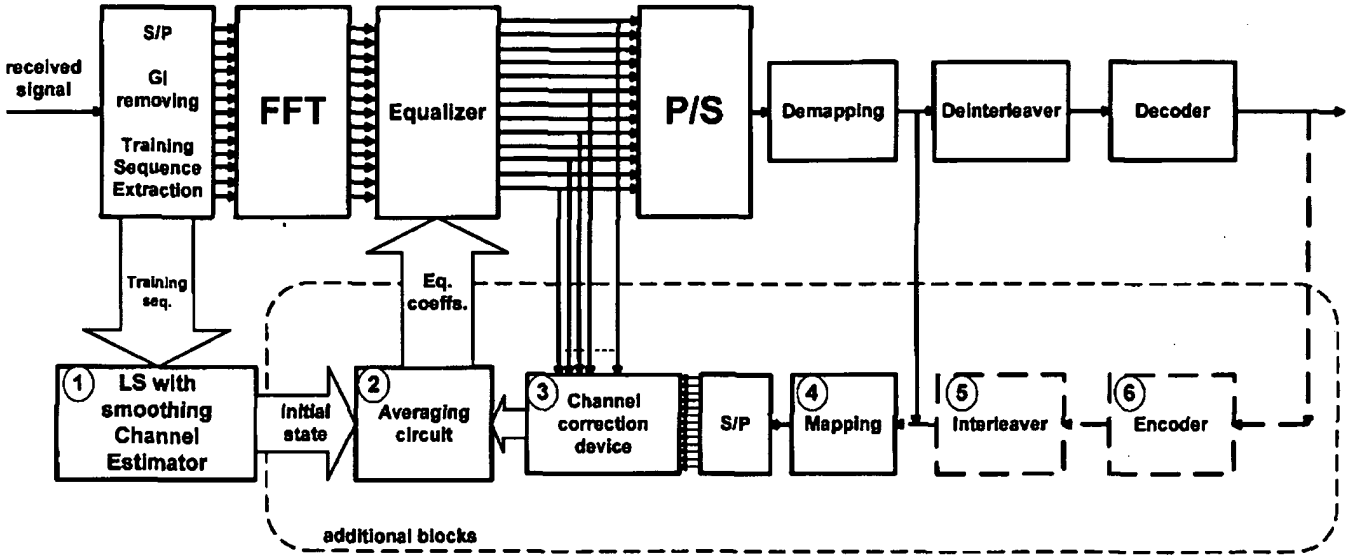

FIG. 1. Structure scheme of the proposed adaptive equalizer.

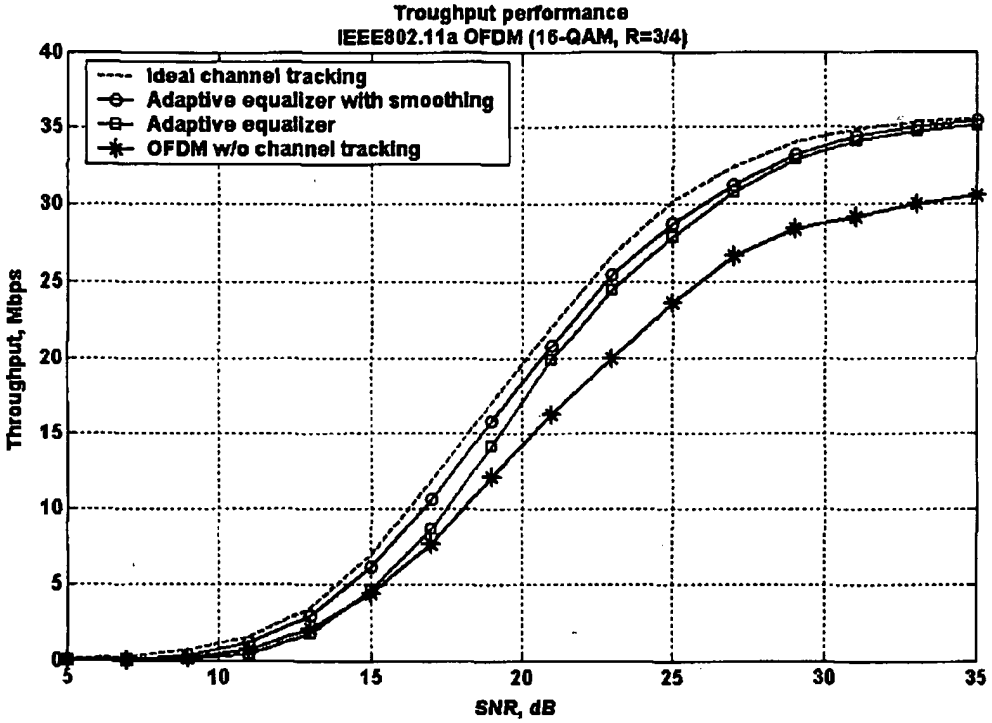

FIG. 2. Throughput performance of OFDM system (16-QAM, R=3/4) for Jakes channel model (f_d=50Hz).

4. Value of your invention to Intel (how will it be used?).

The proposed scheme can be used as a part of OFDM transmitter (in particular, wireless LANs devices either hardware or software, based on IEEE Std 802.11a). It also can be suggested for Intel participation in the development of new next WLANs generation and enhancement of current IEEE Std 802.11a.

5. Explain how your invention is novel. If the technology itself is not new, explain what makes it different.

The main differences from previous work is:

- Smoothing the channel estimate both in frequency and in time domain to improve performance.
- Simplified decision-directed feedback – reducing complexity without performance degradation.
- Exploiting "block averaging" instead of "moving average" decreases computational burden and economizes memory.
- Equalizer coefficients smoothing in frequency domain improve equalizer performance.

6. *Identify the closest or most pertinent prior art that you are aware of.*

[1] Funada, R.; Harada, H.; Kamio, Y.; Shinoda, S.; Fujise, M.; A new amplitude and phase compensation scheme under fast fading environment for OFDM packet transmission systems; Vehicular Technology Conference, 2001. VTC 2001 Fall. IEEE VTS 54th , Volume: 4 , 2001 Page(s): 2093 -2097 vol.4

In this paper adaptive channel equalizer for OFDM system was proposed. But this scheme exploits sophisticated decision feedback and does not exploit smoothing in frequency domain.

[2] Jakes W. C., Microwave Mobile Communications, John Wiley & sons Inc., New York, 1974.

Channel model used for simulations.

[3] Maltsev A. A., Pudeyev A. V., Sadri A. S., Adaptive Channel Estimation For Orthogonal Frequency Division Multiplexing Systems Or The Like, Patent application P15083 (pending).

Previous disclosure with similar approach to the problem of channel estimation

7. **Who is likely to want to use this invention or infringe the patent if one is obtained and how would infringement be detected?**

Potential users of this invention are developers of OFDM systems.

HAVE YOUR SUPERVISOR READ AND FORWARD IT ELECTRONICALLY VIA E-MAIL TO "INVENTION DISCLOSURE SUBMISSION"

DATE: March 7, 2003 SUPERVISOR: Ali Hedayati

BY APPROVING, I (SUPERVISOR) ACKNOWLEDGE THAT I HAVE READ AND UNDERSTAND THIS DISCLOSURE, AND RECOMMEND THAT THE HONORARIUM BE PAID

Matter #: **P16742** Intel Grp Atty: **KMS/INTEL** Work Atty: **MAP/INTEL**

Matter Status: ***IN PROCESS***

TYPE OF INTEL PATENT APPLICATION FILE

*Patent: **Utility** **Design** **Reissue** **Reexam** **CPA (C)** **CIP (X)** **Divisional (D)**

Title of File: **ADAPTIVE CHANNEL EQUALIZER WITH DECISION DIRECTED FEEDBACK**

INTEL DISCLOSURE AND FOREIGN FILING INFORMATION

*Disclosure number(s): **30545**

*Product/Process: **OFDM - ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING, IEEE 802.11A**

Intel Committee: **WIRELESS COMMUNICATIONS & CO** Intel Group: **CTG** Intel Division: **CITL**

Foreign Filing: **SELECTED** Direct: **MY; DE; CN; GB**

National Phase: **PCT**

Notes: **P16742 (30545) - OPENED AND ASSIGNED TO MIKE PROKSCH/INTEL PER CASE ASSIGNMENTS FROM JB 4/17/03 - CP.**

*INTEL ABSTRACT CODES (Check One or More)

__PROCESS (C1)
__N or P MOS (C1A)
__Equipment (C1B)
__CMOS (C1C)
__Contacts (C1D)
__Flash (C1E)
__GaAs and SOS (C1F)
__Circuit element (C1G)
__Isolation/Insulation (C1H)
__BiCMOS (C1I)
__Analysis/Testing (C1J)
__Etching/Planarization (C1K)
__Metal (C1L)
__Poly silicon (C1M)
__Passivation (C1N)
__Masking/Resist (C1O)
__Deposition (C1P)
__Implantation (C1Q)
__DRAMs (C2)
__Sense amp (C2A)
__SRAMs (C3)
__Sense amp (C3A)
__EPROMS (C4)
__P-channel (C4A)
__N-channel (C4B)
__Flash (C4C)
__EE (C4D)
__Sense amp (C4E)
__Solid-State disk (C4F)
__Flash Card (PCMCIA) (C4G)
__Multibit Cell (C4H)
__Redundancy (C4I)
__Blocking (C4J)
__Write Automation (C4K)
__Minicard (C4L)
__ Camera (C4M)
__ FMM (C4N)
__ Firmware Hub (FWH) (C4O)
__ Security (C4P)
__ Small Block (C4Q)
__ FDI (C4R)
__ Interface (C4S)
__ Connector (C4T)
__ Cell Phone (C4U)
__ Charge Pump (C4V)
__ Audio (C4W)
__ Microprocessor (C5)
__ Embedded (C5A)
__Buses Input/Output Devices (C5B)
__Protocol/CPU Interfacing (C5C)
__Adder/Multiplier Units (C5D)
__Numeric (C5E)
__Video/Graphics (C5F)
__Cache/memory Hierachy/ Memory/Virtual Memory (C5G)
__Memory Management/ Protection/Addressing (C5H)
__Instruction/Inst. Decoding/ Microcoding/Sequencing/ Microprogrammed Control (C5I)
__Pipeline/Parallelism (C5J)
__Clocking/Clock Generation/ Clock Multiplication (C5K)
__Addressing/Addressing Modes (C5L)
__Vector Processing (C5M)
__Registers/Files/Stacks (C5N)
__Multiprocessing/Dual (C5O)
__Initialization/Testing/ Debugging (C5P)
__Program/Program Control/ Interrupt/Status/Faults Exceptions (C5Q)
__RISC (C5R)
__Redundancy (C5S)
__SYSTEMS (C6)
__Bus (C6A)
__Supercomputers (parallel multiprocessors) (C6B)
__Compilers (C6C)
__Test Equipment (ICE) (C6D)
__BIOS (C6E)
__PCMCIA (thin removable functionality cards, i.e., memory, modem, network, etc.) (C6F)
__Magnetics (bubble memories) (C7)
__Buffers (C8)
__Packaging/Mounting/ Connector (C9)
__Logic (C10)
__Neural (C11)
__Miscellaneous (C12)
__General Memories (C13)
__Redundancy (C13A)
__Rambus-compatible (C13B)
__General Circuit (C14)
__Peripherals (C15)
__ROM (C16)
__Timing Clocks (C17)
__Power/Regulation (C18)
__Networks (C19)
__PLD (C20)
__Compression/Decompression (C21)
__Video/Graphics/Audio (C22)
__ Algorithm (C22A)
__ System (C22B)
__ Sensor (C22C)
__ Optics (C22D)
__ 3D (C22E)
__ Display (C22F)
__ Graphics Device (C22G)
__Test Equipment (C23)
__Video Teleconferencing (C24)
__Communication (C25)
__ Software (C26)
__ Graphics (C26A)
__ Audio (C26B)
__ Compiler (C26C)
__ Operating System (C26D)
__ Drivers (C26E)
__ Other (C26F)
__ IAL (C27)
__ Internet/WWW Applications (C27A)
__ Java Applets. (C27B)
__ User Interfaces Consumer (C27C)
__ Appliances Portable (C27D)
__ Computing (C27E)
__ Compilers (C28)
__ Java Compilers (C28A)
__ Java Just-in-Time (C28B)
__ IA64 Compilers (C28C)
__ Optimization (C28D)
__ Circuits (C29)
__ New Logic Family (C29A)
__ Data Path (C29B)
__ Chipsets (C30)
__ Memory Control (C30A)
__ Bridging (C30B)
__ Firmware Hub (C30C)
__ Design Tools (C31)
__ Circuits (C31A)
__ Layout (C31B)
__ Logic (C31C)
__ Validation/Test (C31D)
__ Low Power (C31E)

continued next page..

*Mandatory for original patent application. File will not be opened unless mandatory information is provided.

*INTEL ABSTRACT CODES (CONTINUED)

- __CIRCUIT (C32)
  - __A/D (C32A)
  - __D/A (C32B)
  - __Amplifier (C32C)
    - __ OP (Ooperational) (C32C2)
    - __ RF (Radio Frequency) (C32c3)
  - __Isolator (C32D)
  - __Receiver (C32E)
    - __Jitter Attenuator (C32E2)
    - __FM Demodulator (C32E3)
    - __Antenna Interface (C32E4)
  - __Line Driver (C32F)
  - __PLL (C32G)
    - __Frequency Multiplier (C32G2)
  - __Time Recovery (C32H)
  - __Filter (C32I)
    - __Adaptive (C32I2)
    - __Switched Capacitor (C32I3)
    - __Equalizer (C32I4)
    - __Echo Canceller (C32I5)
  - __Detector (C32J)
  - __Signal Generator (C32K)
  - __Oscillator (C32L)
  - __TEST (C32M)
    - __BIST (BUILTIN-S-TEST) (C32M2)
- __CODING/MODULATION. (C33)
  - __Viterbi (C33A)
  - __Block (C33B)
  - __Trellis (C33C)
  - __FM (C33D)
  - __QAM (C33E)
- __HUB/REPEATER (C34)
  - __Ethernet (C34A)
    - __MAC (C34A2)
    - __PHY (C34A3)
  - __Ring (C34B)
- __MODEM (C35)
  - __ Cable (C35A)
  - __ DSL (C35B)
  - __ PSTN (C35C)
    - __ Voice and Data (C35C2)
  - __ Wireless (C35D)
- __ NETWORK MANAGEMENT (C36)
  - __ Agent (C36A)
  - __ Network Discovery (C36B)
  - __ Network Topology (C36C)
    - __ Fault Tolerance (C36C2)
  - __ Policy Based Management (C36D)
  - __ PROXY *C36E)
  - __ Software Distribution (C36F)
  - __Virus Protection (C36G)
- __ NETWORK OS (C37)
- __ NIC (C38)
  - __Architecture (C38A)
    - __Bus Master (C38A2)
  - __ATM (C38B)
  - __Device Driver (C38C)
  - __Ethernet (C38D)
    - __MAC (C38D2)
    - __PHY (C38D3)
      - __Media Attachment (C38D4)
      - __Media Independent Interface (C38D5)
- __ NETWORK PROCESSOR (C39)
  - __Multi-threaded (C39A)
  - __Architecture (C39B)
    - __Instruction set (C39B2)
  - __Compiler (C39C)
  - __Bus (C39D)
  - __Memory (C39E)
  - __Micro-architecture (C39F)
  - __Memory Controller (C39G)
  - __Switch (C39H)
  - __Debugging (C39I)
- __ NETWORK COMM. PROTOCOLS (C40)
  - __Internet (C40A)
  - __Audio or Video (C40B)
  - __Web Caching (C40C)
  - __Bus, Method (C40D)
  - __Wireless (C40E)
  - __Home Networking (C40F)
    - __Phone Line (C40F2)
    - __Power Line (C40F3)
    - __Wireless (C40F4)
- __ SWITCH/ROUTER (C41)
  - __ATM (C41A)
  - __Ethernet (C41B)
    - __MAC (C41B2)
    - __PHY (C41B3)
  - __Load Balancer (C41C)
  - __XML (C41D)
  - __Routing (C41E)
- __ SECURITY (C42)
  - __Cryptography (C42A)
  - __Smartcard (C42B)
  - __VPN (C42C)
  - __Access Control (C42D)
- __ TELEPHONY (C43)
  - __Call Controll Features (C43A)
  - __Circuits (C43B)
  - __Fax (C43C)
  - __ISDN (C43D)
    - __Bridge (C43D2)
  - __PBX (C43E)
  - __Video Conferecing (C43F
  - __Voice/Speech Processing (C3G